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ABSTRACT

This in-depth case study explored the successes and struggles of elementary teachers as they implemented "Investigations in Number, Data, and Space," a K-5 research-based mathematics curriculum that offered students connected and meaningful mathematical problems and in-depth thinking. Data collection and analysis were based on the Zone of Proximal Development concept, which provided a context for the collaborative learning needed to implement an activity-based curriculum. Researchers observed four 5th grade teachers and collected data from interviews, informal conversations, and questionnaires. Results found that teachers' pedagogical beliefs changed when their students or colleagues experienced success with newer learning objectives and newer teaching methods. Their pedagogical beliefs changed from being teacher-centered to student-based when they took time to create a collaborative environment where mathematical discourse was encouraged. Results also found that the classroom-based approach for conducting an inservice professional development program was effective. Key factors needed for teachers to successfully implement such a curriculum included: providing inservice courses, having a mathematics resource person in the building, broadening teachers' mathematical content knowledge, and coordinating teachers' collaborations by enhancing more dialogues with teachers as a team or with other district colleagues. (SM)

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Practicing Elementary Teachers' Perspectives Of "*Investigations*" Curriculum

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Abstract

This study is an in-depth case study using qualitative approaches to explore the successes and struggles teachers experience for the first or second time they implement *Investigations in Number, Data and Space,* a K-5 field-tested curriculum. Data collection and analysis was conducted based on *Zone of Proximal Development* (ZPD) concept, which provides a context for the collaborative learning needed to implement an activity-based (investigations) curriculum.

The study describes the multiple realities that existed and documents the types of support that teachers would like included in the classroom. The study found that teachers' pedagogical beliefs change when their students or colleagues experience success with newer learning objectives and use of newer teaching methods respectively. Teachers pedagogical beliefs do change from being teacher-centered to student-based when they take time to create a collaborative environment where mathematical discourse is encouraged. It also found that the classroom-based approach for conducting an in-service professional development program was effective.

This study focused on only four teachers but the findings provide useful insights to School Districts that adopt *Investigations*. The way ahead in this 21st century is to teach mathematics using research-proven instructional approaches. This study supports other research that calls for supportive, effective, and continual professional development and becoming a reflective teacher.

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Introduction

This study explored the implementation of *Investigations in Number, Data and Space* (1998), a reformed curriculum, in three 5th grade mathematics classrooms. *Investigations* is a K-5 research based mathematics curriculum whose objectives are to offer students connected and meaningful mathematical problems and in-depth thinking. *Investigations* goals, such as students should (i) express their mathematical thinking through drawing, writing, and talking and (ii) develop their own strategies of mathematical relationships, are based on postmodernism, constructivism and sociocultural worldviews. These perspectives have become the most influential models in the teaching and learning of reform mathematics (Lesh & Lovitts, 2000; Steele, 2001).

The teaching of mathematics in the past emphasized certainty, structure, procedure, algorithm, logic and formality (Becker & Jacobs, 2001; Goldsmith, Mark & Kantrov, 1998). Such traditional teaching made mathematics dull and difficult to some students (Schoenfeld, 1983). Currently, many mathematics educators and researchers are advocating a reformed mathematics curriculum (Brooks & Brooks, 1999; Marzano & Kendall, 1996; Kilpatrick, Swafford & Findell, 2001).

Rationale

Reformed mathematics curricula are student-focused and standards-based. A central notion of these curricula is that knowledge is socially constructed. Understanding in learning mathematics is enhanced when students participate by doing, as opposed to the traditional pedagogical ways where the learner observes what the teacher does and merely repeats the facts, procedures, formulae and rules.

Practicing teachers (without in-service training) as the implementers of the curriculum are facing a number of difficulties such as reflecting on students thinking. Applying the reform requirements has created a dilemma because these teachers have learned, observed, practiced and taught traditional mathematics, while reform curricula requires innovation.

> The radical and multidimensional character of the innovations currently being imposed -- for example, the major restructuring of teaching methods and the implementation of new learning objectives – has major consequences for the school at various levels, and the professional functioning of teachers in particular. (van den Berg, 2002, p. 597)

An investigation of the tension arising within each teacher, between traditional views and reformed approaches to teaching mathematics is the main phenomenon under investigation in this study. The postmodernist notions such as multiple perspectives and reflexivity are a challenge for those who believe in one right way, truth, and objectivity.

The instructional changes called for in the implementation of *Investigations* mathematics curriculum raise a number of questions. It demands for instance, a move from competitive learning to cooperative learning and other varied strategies based on the multiple intelligence theory (Gardner, 1983; Willis & Johnson, 2001). How does a practicing teacher come to change his or her teaching practice? A majority of the elementary teachers are underprepared in teaching mathematics as meaning making and not rule following (Lowery, 2002).

Literature Review

Teacher change depends on several intertwined factors, such as a teacher's background knowledge of mathematics (Shulman, 1986), and a teacher's attitude (Vacc & Bright, 1999). The aim of the study is to explore teachers' perspectives, as well as what meanings they make of *Investigations*, in the light of their pedagogical beliefs and dispositions. To situate this study in existing literature, studies on the relationship between beliefs about teaching and instructional practice are reviewed.

The review is done in three sections. The first section defines the key concept of the study and how other studies perceive teachers' pedagogical beliefs. The second section discusses research findings on the congruence between teachers' beliefs and their instructional practice. The need for this study is summarized in the last section.

The Teacher's Pedagogical Beliefs

Raymond (1997) describes mathematics beliefs as personal judgments about mathematics and how it is formulated from experiences. These beliefs include the nature of mathematics, its learning and teaching. Thompson (1992) views beliefs as an aspect of conception, and expounds on a teacher's conception of mathematics teaching and learning as:

> What a teacher considers to be desirable goals of the mathematics program, his or her own role in teaching, the students ' role, appropriate classroom activities, desirable instructional approaches and emphases, legitimate mathematical procedures, and acceptable outcomes of instruction. (p. 135)

According to van den Berg (2002), beliefs are personal truths that "typically reflect the teacher's opinions regarding the processes of teaching and learning" (p. 579). These

definitions suggest that mathematics beliefs do stem from prior school experiences (Brown & Borko, 1992), including experiences as a mathematics student, the influence of previous teachers and of teacher preparation programs, and prior teaching episodes. From the foregoing argument it seems, that there is a link between beliefs, prior experiences and one's knowledge base. Thompson (1992) notes that the distinction between beliefs and knowledge is fuzzy and futile due to the close relationship between the two. Does this imply that teacher beliefs are bound to change because the knowledge base varies and changes with time? This study refers to all the underlying ideas of the above definitions of beliefs (e.g., teacher role, knowledge, prior experiences, approaches, nature of math) as teacher's pedagogical beliefs, as they pertain to instruction.

Researchers (Ernest, 1989; Kuhs & Ball, 1986; Lerman, 1990) have developed models of teachers' pedagogical beliefs. Thompson (1992) synthesized these models into three groups, namely (a) the problem-solving/fallibilist /learner-focused view, a teacher in this group would be a facilitator, creative and an enquirer; (b) the platonist/absolutist/conceptual content-focused view, a teacher in this group beliefs that math is unchanging and can be discovered but not created; and (c) the instrumentalist/ performance content-focused view with emphasis on performance, a teacher categorized in this model perceives mathematics as accumulation of facts and skills for future utilitarian value. I chose to use these models as a beginning framework for analyzing and classifying teachers' beliefs.

The Relationship Between Teacher's Pedagogical Beliefs And Instructional Practice

A key idea gleaned from research studies on teacher's pedagogical beliefs is that teachers bring experiences and prior understandings that shape the learning and teaching

of mathematics (Ball, 1988; Brown & Borko, 1992; Schifter, 1993; Simon, 1993). That is, the teachers' knowledge of mathematics and pedagogy translate into practice through the filter of their beliefs (Ball, 1996). A study by Manouchehri and Goodman (1998) provides evidence that implementing a mathematics curriculum depends on teacher's perceptions and images of the mathematics they teach. Speer's (2002) dichotomy of teachers beliefs as "professed beliefs" and instructional practices as "attributed beliefs" affirm the connection between the two.

The above finding of the relationship between beliefs and practice implies that more research in this area ought to be done, especially in this mathematics reform era. The continued cherishing of traditional pedagogical beliefs slows the process of mathematics reform. Hence, the findings of this study may shed light on issues that are vital for the successful implementation of reform curriculum. Thompson's (1992) synthesis and van den Berg's (2002) review demonstrate that studies in this area have been conducted mainly with high school mathematics teachers (Cooney 1985; Kesler, 1985; Thompson, 1984), higher education teachers (Speer, 2001), and in pre-service and in-service teacher education programs (Hollifield, 2000; Quinn, 1997). Besides TERC and Klein and Remillard's (2002) study, there is hardly any research on practicing elementary teachers that has been conducted, especially with regards to aspects of the *Investigations* curriculum.

Speer (2001) remarks that the early studies on beliefs and practices fail in the fine-grained significant details of the relationship between the two. Her study of the relationship between questioning technique (an aspect of practice) and teaching assistants' belief about understanding in reform-oriented calculus courses was specific.

Chow's (2002) research was specific too. She examined in-service elementary teachers' beliefs and practice of number sense. Current studies are becoming more focused (Banker, 2002; Cakiroglu & Haser, 2002) by looking at beliefs of an issue and its relationship with an aspect of practice. This study focuses only on collaborative learning as one aspect of practice.

Besides findings of consistencies between teachers' belief and instructional practices, other studies have shown no correlation (Carter, 1992; Cooney 1985; Shaw, 1989; Thompson, 1984). Speer (2002) attributes inconsistencies to a lack of in-depth probing and shared understanding between teachers and researchers in the meanings of terms.

The Need For This Study

This study explores the teachers past experiences and how the past impacts on their practice. The argument being that *Investigations* requires use of inquiry methods of instruction. Yet, a majority of the practicing elementary teachers have pedagogical beliefs, values and experiences that are deeply rooted in the traditional way of thinking, an adherence to a fixed curriculum, heavy reliance on textbooks, and dissemination of information from the teacher to the students (Brooks & Brooks, 1993).

There is a need for mathematics educators to know specific meanings teachers make of particular reform curriculum. Little is known about teachers' pedagogical beliefs and their meaning-making process of the *Investigations* curriculum.

Many teachers do not believe that learning mathematics is a social process in which each individual learns through social interaction, meaning negotiation, and shared understanding. Thus this study also investigates teachers' views on mathematical learning

communities (Lave & Wenger, 1991), and whether or not they employed collaborative learning. The National Council of Teachers of Mathematics (2000) teaching principle states that "effective mathematics teaching requires understanding what students know and need to learn and then challenging and supporting them to learn it well" (p. 16). This is the basis of the activities in *Investigations*. Meaning arises out of these interactions and is modified through interpretive processes.

Finally, there is growing evidence supporting the view that teachers must possess some degree of confidence about their understanding of the subject content in order to move into tasks that go beyond simply defining and presenting topics (Brown & Borko, 1992). How is this confidence gained? A study on preparing elementary teachers for the new millennium (Metheny & Davison, 2000) found that teachers' confidence in mathematics improved when the teachers were exposed to situations where they could construct knowledge concerning new mathematics concepts and pedagogy.

In addition, teachers must have knowledge about the pedagogical issues related to teaching content effectively (Shulman, 1986), what McClain and Cobb (2001) call a "sense of knowing in action" (p. 236). Studies on teacher development acknowledge the need for teachers to develop a new understanding before helping students (Manouchehri & Goodman, 2000; Shulman, 1986). Current research suggests that any development program should explicitly address the issues of content knowledge, pedagogical skills and reasoning that are necessary for implementing innovative curriculum and instruction. Such a program should not only incorporate a presentation of the theoretical perspectives regarding the topic, but also specific recommendations for teacher planning processes and teacher personal growth in content and pedagogy. This calls for intensified in-service

training before teachers can successfully implement a new curriculum, an issue beyond the scope this study. Again, Schifter (1996) notes "new pedagogy means developing an attitude of inquiry toward classroom processes" (p. 498) and has nothing to do with keeping up with innovative techniques or strategies. Thus this study looked at the change teachers undergo as they implement *Investigations* in their classrooms.

The exploration of teachers' perspectives and what meanings they make of *Investigations* also sheds light on the similarities and differences between the implemented and intended curriculum. Participating teachers in this study had little support with *Investigations*. Yet, they are being called upon to actualize the teaching of mathematics as a social and as a cultural exercise. They are expected to use newer teaching strategies, assess understanding through projects, journals, and other means, and choose from a variety of manipulative, calculator, and other technologies. Teachers are expected to act more as facilitators, that is, to organize the learners in collaborative learning groups, incorporate inquiry-based mathematics activities, use concrete materials for meaningful learning, emphasize connection, empower learners, and create non-competitive and safe environments.

Teachers hold varied beliefs on various issues and there are a myriad of issues impinging on pedagogy. For example, Thompson's (1984) study found Kay's view of mathematics teaching to be consistent with her teaching, but found her view regarding the practical value of mathematics to be inconsistent. There is need for more focused studies, hence this study's focus on collaborative learning. The foregoing discussion begs three key questions that this study sought to investigate.

1) What are practicing elementary teachers' pedagogical beliefs about *Investigations* curriculum?

2) How do teachers' meaning making of *Investigations* influence their practice?

3) What changes do teachers undergo when they implement *Investigations*?

The study uses a qualitative-interpretive research approach, as it pertains to meaning making (Thompson, 1992; van den Berg, 2002). This study plays a part in the recommendation put forward by Riordan and Noyce (2001) that, a "closer examination and qualitative analysis of implementation in individual schools" would "provide information about what determines successful implementation of standards-based curriculum program" and "elucidate how to implement these programs for maximum effect" (p. 392).

Theoretical Framework

This study takes a sociocultural approach. The sociocultural perspectives have provided mathematics educators with several teaching shifts to enable teachers to teach meaningfully. Teaching of mathematics should no longer be viewed as a neutral subject that is devoid of social, cultural, class, and political contexts. McCaffrey, Hamilton, Stecher, Klein, Bugliari and Robyn (2001) list five of these shifts as:

> (a) view mathematics classes as mathematical communities rather than a collection of individuals; (b) use logic and mathematical evidence to verify results rather than rely on the teacher as the authority; (c) emphasize mathematical reasoning rather than memorizing procedures; (d) focus on conjecture, inventing, and problem solving rather than the mechanical answer finding; and (e) make

connections among ideas and applications of mathematics rather than seeing them as isolated concepts and procedures. (p. 494)

To assess the processes and meaning making of *Investigations,* that is, insights into teachers' pedagogical beliefs, and observe changes in teachers' practice or mathematics discourses calls for a sociocultural stance. This perspective has the language for the construction and deconstruction of culture and institutional context, and is a lens through which one can examine how history, culture, politics, and the social background (for example, traditions, values, beliefs) impact on instruction, and thereby provide in-depth meaningful information (Forman, 1996; Vygostsky, 1978; Werstch, 1991).

Sociocultural aspects are numerous and interconnected. An aspect used in this study is the concept of the *Zone of Proximal Development* (ZPD), which is the difference between what a learner can accomplish alone and what a learner can accomplish in cooperative learning with an expert (adult, guide, teacher or a more capable peer). The teacher mediates the learners' learning through social interaction and classroom discourse (Jaramillo, 1996).

In the ZPD, a sense-supporting context for learning is offered and a common practice is based on collaboration. The ZPD is the context for the collaborative learning needed to implement an activity-based (investigations) curriculum. The ZPD helps to explain how social and participatory learning take place (John-Steiner & Mahn, 1996). Learners understand better as they participate by doing, communicating and reasoning using the language of the mathematics culture. Kieran, Forman, and Sfard (2002) postulate that "[t]hinking is conceptualized as a special case of the activity of

communication, and learning mathematics means becoming fluent in a discourse that would be recognized as mathematical by expert interlocutors" (p. 5).

Collaborative learning means the teacher needs to create a safe classroom environment (Hausfather, 1996) because this enhances interaction between students of varying abilities and allows for talking, writing, watching, listening and sharing of ideas. It is through this conceptual view of learning that the study bases its findings.

A number of issues take place in a classroom environment. Classroom observations were made on how the teachers facilitated, launched, explored, shared and summarized an activity (*Investigations* being an activity-based curriculum) as a way to get data on their practice. On the other hand, data about teacher's beliefs are what the teachers stated in the interviews and wrote on the questionnaires.

Methods

An observational case study (Bogdan & Biklen, 1998; Burns, 2000) approach was used to explore teachers' pedagogical beliefs and the implementation of *Investigations* curriculum during the 2001 – 2002 academic school year. The Sept –May, nine-month period provided ample time to be acquainted with the institutional context, build rapport with the participants and collect grounded data.

Setting And Participants

The data were gathered from three 5th grade classrooms with student ages ranging from 10-12 years at Hawse Elementary School. Hawse is in a mid-sized city in a New York State school district with 83.7% of the student population qualifying for free lunch. The middle schools in this district use *Connected Mathematics* and to align the K-5 curriculum with middle schools, *Investigations* was piloted in a few schools. Purposive

sampling was used to select Hawse and the fifth grade classes. These classes had the necessary instructional materials and kits and the teachers willing to try a new curriculum. The data were collected during this pilot phase though currently (2002-2003 onwards) all teachers in the district are expected to implement *Investigations* since it has become the adopted curriculum.

There are nine units of *Investigations* at grade 5, namely:

- *Mathematical Thinking*
- *Name That Portion*
- *Building on Numbers You Know*
- *Measurement Benchmarks*
- *Patterns of Change*
- Picturing Polygons
- Containers and Cubes
- Kids, Cats, and Ads
- Between Never and Always

No teacher was able to cover all the nine units in the academic year. Only one of the classes covered the five italicized units above. Findings of the study are based on two units that were covered in all the three classes:

1. *Mathematical Thinking* - deals with key landmarks in number system (i.e., factors and multiples of powers of 10).
2. *Name That Portion* - concerns the idea of equivalence using different representations (fractions, percents & decimals) and models (grids, clockface).

Four 5th grade teachers participated in this study. Two were male, Leroy and Tim (pseudonyms) and each had his own class. The other two teachers were female, Doty and Kim in one class, with an assistant. Before *Investigations*, the teachers were using *Mathematics in Action* (1992) textbooks. The teachers planned topics they wanted

covered for the week as a team. The three classrooms are very close to each other. Mathematics was taught daily in all three classes at the same time from 11.40 a.m. to 12.30 p.m - the last period before the lunch break.

Data Collection

Participant observation, informal conversations, questionnaires, open-ended interviews and in-depth tape-recorded interviews were used to collect the data.

Participant observation was conducted, once a week (on different days) in each class during the mathematics lesson throughout the nine months and recorded as field notes. These provided a clear picture of the instructional strategies used mainly by a teacher.

The interviews were used to obtain data on teachers' beliefs and their meanings of *Investigations*. The interview questions arose from observational field notes. They also arose from the answers teachers gave on the questionnaires (**Q**). In total, three tape-recorded interviews (40 min.) and two questionnaires were administered to each teacher. The five were administered as shown in the table below:

End of 1st two Classroom Observations (**CO**)	End of next 3 **CO**	End of next 3 **CO**	End of next 3 **CO**	End of next 3 **CO**
1st Interview (**I**)	1st **Q**	2nd **I**	2nd **Q**	3rd **I**

This timing gave me an opportunity to observe if what they said or wrote was executed in class.

I held some planned and impromptu conversations with the teachers, either individually or as a group, regarding instructional approaches. These talks were written down soon after, as reflections. Conversations occurred mainly on Mondays, Tuesdays and Wednesdays at 9.50-10.30 a.m. when the students went for 'specials' (Music, Art, Physical Education or Library) freeing teachers, as well as during some lunch breaks.

Artifacts such as materials used in teaching and photographs of posters and manipulatives used in the class were recorded.

Limitations

Constrains to this study includes (a) a small sample size of participants, since only four teachers participated in this study; (b) purposive sampling of the study settings. Besides, the teachers willingness to pilot *Investigations* I was working in this school as a graduate assistant as well. I was the *Investigations* resource person in this school during the 2001-2002 academic year. The answers I gave to teachers' questions or the suggestions I offered may have made them be more reflective to reform requirements although teachers were not obligated or pressurized to implement my ideas; and (c) a researcher biases, given that I am a mathematics education student, probably my worldview influenced my data collection.

Data Analysis

Modified analytic induction (Bogdan & Biklen, 1998) was used. Analysis of data collected began after the first two classroom observations. I coded the data based on my conceptual framework of collaborative learning, and on grounded data (fieldnotes). From the data the codes "activity," "content," "group work," "student engagement," "teacher assisting students," "lecture," and "sharing" emerged as the main categories.

I derived the interview questions from the field notes to inquire about teachers' pedagogical beliefs (to inquire why they practiced as they did). The first interview results were analyzed based on the definitions of teachers' pedagogical beliefs as found in the literature review section. In the third observation I verified if what the teachers stated in the interviews was implemented. The looping of what I observed in the classrooms, what

the teachers said, and wrote on the questionnaires was an on-going, continual process throughout the study as I searched for recurrent patterns of practice and refinement of teachers' meanings of *Investigations*.

Results

For each class, a synopsis of the classroom and a brief teaching history of the teacher is given followed by a detailed description of the findings of each teacher's pedagogical beliefs, and its relationship to practice and meanings of *Investigations*. Discussions on changes teachers undergo when they implement *Investigations* are included.

Class A

Leroy was the teacher in this class of 24 students where ten were boys. He had no aide in the class and his classroom was decorated with mathematical posters and resources such as a chart of "Fractions and Decimal Equivalents," a chart showing different decimals, with their corresponding fractions, place value and name (0.3=3/10 = ... = three tenths). Some of the posters were bought (ready-made) while the teacher and the students hand-made the rest. The improvised posters and charts (e.g., Everyday Use of Fractions, Percents, Decimals) varied from time to time depending on key ideas being taught and learned.

Leroy holds a masters degree with a specialization in Reading and is one of the decision makers on the district's curriculum committee. He has 27 years of teaching experience and has been at Hawse for the last 25 years. He stated that he loves teaching at the intermediate level. Before coming to Hawse he was a substitute teacher, an exposure

that endowed him with worthwhile experiences of teaching at all grade levels be it elementary, junior high and high school levels.

Leroy has experienced different curricula in his career and completed in-service courses sponsored by the district to adjust to the needs of the curriculum of the day but not for *Investigations*. When he first joined the district, it had an individualized learning type of curriculum known as the "levels program" – where students worked at their pace and ability, and levels that students had to complete in order to master the math program. One particular math program that was an eye-opener to him that he found comparable to *Investigations* was called "Thinking Mathematics." This was his second year in using *Investigations*.

Leroy's Pedagogical Beliefs

Leroy notes that he likes *Investigations* and is pleased with it because he feels it (a) enables students to work at a higher level of thinking, (b) develops students' reasoning skills, (c) gives students' a chance to do a lot of hands-on activities, (d) makes students see exactly why they are doing the activity, (e) creates an everlasting picture in the students' mind, (f) provides students a chance to work with a group, share ideas, come to conclusions and get to know each other socially and academically, and (g) is interconnected. Leroy stated that, "We don't stop using *Investigations*. It's continuous, no matter what area we are doing in Math."

Leroy holds a practical and integrated view of mathematics. He sees his role as that of equipping all students with basic mathematics skills for use in future schoolwork and everyday life and letting the capable students learn as much as they can. He incorporates *Investigations* into the writing program, blends mathematics with science and social

studies whenever appropriate "so that kids can see that we don't do math during math - math is all around us no matter what we do."

Leroy professed that he would like to teach students to be more well-rounded persons; this belief could be seen in the types of examples he elicited from his students or proffered himself; his utilization of newspapers so that students could see how mathematics applies to real-life activities, and in the artifacts he had in his room (i.e., a poster of an odometer showing mileage, a gas meter (this sale $, gallons, price per gallon) - to illustrate to students everyday uses of decimals).

Relationship Between Leroy's Conception Of Investigations And His Practice

Generally, Leroy's math lesson begins with him focusing students' attention on the objectives to be achieved by the end of the lesson. He then launches the content to the whole class by explaining it with the aid of an appropriate transparency or charts. After this he gives the students an activity/investigation/game to explore in small groups of threes or fours. He groups them heterogeneously by balancing the groups equally and appointing a leader in each, who can take charge, act as a teacher or peer tutor.

Each group member has a role to play (leader, recorder, reporter, and someone to collect the required materials from the table). The students know what is expected of them as a group and follow the teacher's laid-down ground rules. Everyone's opinion counts towards the investigation; the students use their "6-inch" (softer) voices and present their work at the end of it.

As the students work together, Leroy assists groups that need him. He moves around from one group to the other, talking with each, checking and keeping record of their progress and reminding them of time left to the end of task. The spacing among

groups is adequate and the room arrangement allows facilitated interactions both between and among students and teacher.

At the end of the allotted time, each group's speaker reports to the whole class and shares their strategies. Other groups then question them. Leroy too probes further. At the end of the presentations, Leroy showers them with praise for a job well done and urges each student to either pat or hug him/herself. Indeed, students enjoyed congratulating themselves. In closure, he requests students to verbally enumerate key ideas learned and then write it up in their journals. He summarizes and brings the lesson to an end by assigning homework to reinforce the newly learned ideas.

There is a consistency between Leroy's pedagogical belief and his classroom practice. He remarks that group work is "noisy at times but as long as learning is taking place that is what counts." Students presented their strategies whether they were correct or not and if found incorrect, Leroy then turned them into learning moments. There was an element of shared meaning and negotiation going on. Students learned much from one another. The idea of working cooperatively in small groups enhanced students' understanding, communication skills, and built their ability to listen to each other. Leroy also varied group dynamics by holding group work in the form of debates.

Leroy encouraged students to dialogue with him and verbalize their thoughts too; not only to him but also with each other by creating a safe environment. He points out that creating a successful cooperative learning group required good organization on his part, (i) finding the right balance in grouping (consumes a lot of time. In some cases he had to readjust students more than three times to get a successful cooperating group), (ii) conducting individual (one-to-one) conferences to ensure that a student can dialog with

him, (iii) collecting students' sheets and folders periodically to ensure they stayed on task, and (iv) letting students do a self-reflection each week of what he or she has learned in math.

Leroy finds *Investigations* lacking in providing adequate homework reinforcement. He resorts to traditional books to provide more practice or make up his own quizzes. But when asked the need for this practice, he finally complies that if students understand a concept, then "I don't think it is to their benefit to give them a lot of homework."

Leroy, who was using *Investigations* for the second time, admits that it is difficult to begin implementing *Investigations*. "You find yourself reading word for word they way it is scripted. So that takes a lot to be used to …after my second year of utilizing it, there are a lot of things I don't need to go back into the manual to look for." So as time went by he got comfortable with *Investigations* units. Leroy also stated that his shortcoming with *Investigations* was use of technology. He does not know the role calculators play in *Investigations* and he has no experience on how to set-up a computer-based classroom.

Class B

There are two female teachers, Kim and Doty, and a female teacher assistant in this class of 24 students where nine are girls. The classroom was adorned with varied educational posters, charts, students' work and equipment. Two special education teachers usually pull out about five students to work with at designated times.

Teacher Kim

Kim is a special education teacher. She graduated with a bachelor's degree in 1999 and earned a masters degree in 2002 with teacher certification. Kim is a new teacher at Hawse although as she worked on her master's program, she taught in a district middle school for two years, strictly with students with special needs. Her middle school had no math curriculum in place or supplies, so she taught basic math skills (area, perimeter, number sense) from the only textbook available, her own creations and what she heard from her colleagues. Kim works hand-in-hand with Doty taking turns in teaching different subjects. They plan together and she is the key teacher in the afternoon hours or in the absence of Doty.

Kim stated that she loved math as a student, and did well in her exams even though these experiences did not offer her opportunities to explore mathematical ideas and concepts. She describes the way she was taught as non-interactive. It was "Here's a book! I am going to show you a problem. I am going to tell you how to go about attacking the problem. I am going to model it. We're going to do some together in the class. You are going to go to the board and do it and then you are going to do it independently and then hand it to me on a sheet of paper."

Kim's Pedagogical Beliefs

Investigations is Kim's first reformed curriculum in her teaching career. Kim finds it appealing, meaningful, less textbook-centered and has "no drill and kill." She believes in an inquiry-based approach to learning and teaching and being interactive. She likes having charts, hands-on activities and group work. She noted that the sharing and caring aspect as students do an activity enhances their skills to a much higher level as they help

and pull one another up. Kim had this to say about *Investigations* activities: "Just talking and discussing and sharing a strategy is a good way to validate what we are doing." She believes that peer tutoring in *Investigations* enables students to come up with a lot of strategies and to interact with people they might normally not have a chance to interact, thus building on their confidence with each other.

Relationship Between Kim's Conception Of Investigations And Her Practice

Kim did not teach mathematics to the whole class but aided Doty when they split students into smaller groups. At times they put students in groups by mathematical reasoning ability and she worked with the students with the greatest learning difficulties. Most of these students had problems adding two fractions with different denominators and she could help them attempt it by using the clock face. For those who did not know 'times tables' (multiplication), she reminded them of attempting to use the skip counting technique or permitted use of a calculator or a "planner." When all her innovative techniques failed she gave direct instructions, just like the chalkboard instruction. Thus the relationship between her pedagogical beliefs and practice was consistent even though she reverts back to a show-and-tell strategy as a last resort.

Although Kim has just finished her college degree, she acknowledges that her preparation program did not prepare her psychologically to deal with changing teaching strategies. *Investigations* was "doable" to her and frustrating too because the way she was taught math is not the way *Investigations* is taught. Kim's master's program gave her six weeks of math training on using hands-on strategies. She found the training too short and very limited for K-6 mathematics. She stated that, "we simply browsed through a few concepts of 1st, 3rd and 6th grades." She notes that she is a learner all over again as she

helps her students do the activities. "I'm definitely inferior when it comes to math – it's one of my shortcomings."

Kim finds it easier to turn social studies into interactive learning than math. She is interested in getting professionally equipped to teach math interactively. She looks forward for in-service training and finds the talk and meetings they do as a team at Hawse on *Investigations* helpful.

Kim stated, "*Investigations* does not give enough homework to students" and would like an *Investigations* workbook for herself and the students. She proposed that her copy of the workbook should have different strategies and ways of solving problems while the students' workbook, to be more interactive as well as give them enough practice until the concept becomes a part of them.

Teacher Doty

Doty is the key teacher for classroom B and has been in the same classroom for five years. She has 25 years of teaching experience and had a good math background which she attributes to having been born to an engineer father. She started teaching in a special education and resource classes where she taught all the subjects for four years. She moved to a "self-contained" high school classroom where she taught only two subjects and her two colleagues did the rest of the school subjects, on a rotation basis. She stopped to raise her four children and worked as a substitute teacher. When she was ready to go back to full-time teaching she had a class of gifted children for about ten years before the program was abandoned. The gifted program had no math curricula in place and Doty generated her own teaching and learning materials. Unlike her current special needs

students with mixed abilities, teaching the gifted was homogeneous with more similarities than differences.

Doty's first regular class with over twenty students was at Hawse where the curriculum was in place and she had to fit her way of teaching and ideas into the established curriculum. She has undergone in-service training workshops in other areas including cooperative learning, and disciplining but not one for mathematics instruction. She is one of the district's social studies textbook committee members and the contact person for the fifth grade teachers' team. This is her second year with *Investigations*, though she taught very little of it the first year.

Doty's Pedagogical Beliefs

Doty is a holistic person - "kind of a person drawing on all kinds of things when I teach" and thematically oriented. Artifacts in her class speak to this too – roadmaps, phonebooks, bus schedules, varied educational posters ranging from character building to math. She believes in students doing more problems, writing, thinking and applying what they have learned in math. Doty's pedagogical beliefs changed with time.

Fall session: Doty's pedagogical beliefs.

Doty believed in making math more abstract at this 5th grade level by using hands-on activities, group work, and cooperative learning infrequently and not teaching any math unfamiliar procedures. "I have to *over* know it (*Investigations)* to teach it to the students. I am in transition – I have one foot in traditional Math and another in *Investigations* and I think I am going to fall in," remarks Doty.

Spring session: Doty's pedagogical belief.

By the beginning of 2002, Doty changed her beliefs. *Investigations* diverse strategies and its ability to have students engaged made her change her pedagogical beliefs from being the sole authority in class to being ready to learn from the divergent thinking of her students. She points out that *Investigations* needs people to be flexible and ready to come down to the level of the students. She feels *Investigations* is broad in scope and promotes understanding of math as opposed to being rigid.

Relationship Between Doty's Conception Of Investigations And Her Practice

There is a consistent relationship between Doty's belief and her teaching in both sessions.

Fall session.

During the fall session Doty was not implementing *Investigations* fully. She found it overwhelming. A number of factors played a role in her partiality: the new learning, the readings of the teacher's manual and the unlearning to be done were beyond her comprehension. She found it time-consuming too. "I have to read *Investigations* … I like the pictures they show you of what you do with students but traditional math books give better visuals – tells you what you will be doing, … this and that," she argued against *Investigations*.

She lacked confidence due to its newness and the fact that she relied on only the resources that were given. She also felt that she had a lot on her hands already given that her classroom had most of the children with learning disabilities and low reading abilities. Doty says that students "are too conditioned and would rather see a computation problem than write up two different ways of representing 50." Her students had no prior exposure to *Investigations* learning approaches, but had only abstract and procedural

learning. Implementing *Investigations* was frustrating: "I have to do 4th grade array work before I can do 5th grade work." More of the strains too were due to the State exam (Social Studies, Terra Nova) pressures.

Doty's practice was teacher-centered at this period in time (Fall), even though she used *Investigations* during math lessons and the traditional book for homework. The following is an example that is representative of her math practice observed during the fall semester:

Step 1: Review and correction of previous multiplication (mental) math quizzes.

Step 2: Overhead Transparency of 300-chart displayed, then of PUZZLE NUMBER 7 that had: -

Here are four clues for a number puzzle:

My number is even

My number has two digits

My number is a multiple of 9

My number is a square

Find the number(s) that fits the clue?

These clues were written down on the board and the 300-chart was mounted.

Step 3: Questions from teacher and students' answer.

What's an even number?

Which clue would you start with?

Which clue should we use next? …

Step 4: Puzzle NUMBER 8 mounted followed by teacher questions - students' answers.

Step 5: Either class work is done on what teacher just modeled or it was time for lunch. Lesson time occasionally ran out before the lesson could be brought to closure.

Doty handled *Investigations* traditionally, yet it is a student-based curriculum. The lessons were mainly teacher-oriented with the teacher asking leading questions in most cases. Mostly chorus answers were given or if the question was challenging the talented student answered. Her lessons were controlled by the higher-level students' pace. Students feared answering because in her class if a student offers an incorrect solution the student is ignored and someone else is asked to offer the right one. There was hardly any probing as to how one came up with the wrong answer.

"Most students in here fear taking risks! They would rather wait for others to do it. So it is always the bright students solving problems all the time," Doty pointed out to me in a conversation. I asked about creating a safe environment for learning by engaging the students with the activity as a group and then giving them a chance to share their strategies out. She stated, "Group work does not work with my kids. They are very low. Last year I got low kids but this year they are even lower."

Spring session.

When she mixed the two curricula at first, her practice was teacher-centered but when she used only *Investigations*, her students were all engaged and busy and she had no classroom management issues. Performance of her mathematically low-ranked students improved too (Terra Nova results). The change came as a result of her taking time to read through alternative strategies to a problem. "I like how *Investigations* added two fractions by first converting to percents then adding, unlike in traditional math where

we have to find the lowest common multiple (LCM) if the two denominators are different. My students understand percents! …"

Doty was motivated and enjoyed learning together with her students especially on the use of technology. She and her students were able to incorporate the use the computers and calculators with *The Patterns of Change* and *Name that Portion* books respectively. Students from Class C could come join her class for such moments. She noted that her students did not interact with the *Trips* activity properly because she did not organize it properly. She regrets the amount of time she lost at the beginning of the year when she mixed both methods thus making her unable to finish all the *Investigations* units.

Class C

There are 16 students in Tim's class and ten of them are girls. His room is devoid of any mathematical posters, wall hangings or charts except for a calendar. Tim is a family man with four children. He has been teaching for the last 25 years after retiring from playing basketball professionally. The year 2001 was his 13th year at Hawse but his first year as a 5th grade teacher. During his previous years, he had taught a 4th grade class and he felt his method of teaching had helped his former students perform well on the NYS Math State Exam. He plans to retire soon. This is Tim's first time using *Investigations*.

Tim's Pedagogical Beliefs

Tim likes *Investigations* and acknowledges that it is a worthwhile curriculum since "*Investigations* has a lot of critical thinking material in it." It gives students more meaningful strategies as opposed to traditional mathematics. "Students come up with different strategies but the results are the same," he stated. It puts

students in groups and has more manipulative that students' experience more than the traditional math.

Relationship Between Tim's Conception Of Investigations And His Practice

His practice was teacher-based and a drill type of teaching. The teacher knew it all, and sought out for the one right answer from the students, and praised the students providing the correct answers. Tim covers a lot of math problems with students irrespective of the curricula. A general strategy of his lesson was that there was always someone showing the whole class how to solve a mathematical question, either him or a volunteer. Volunteering students wrote their answers or working on the board without explaining their strategies. Tim always jumped in and explained the process and then moved on to the next problem.

There is inconsistency in the relationship between Tim's beliefs and practice. His practice did not engage all students in learning. The same few students repeatedly went to solve problems on the chalkboard. Usually there were at least four students disengaged from the whole class instruction. At times very little mathematical content was covered because the teacher spent more time in classroom management to teaching math content. He did not use a lot of hands-on activities. He felt responsible for the learners and feared they would hurt each other with the math tiles thus landing him in trouble. Even though he used other representations to explain a concept (graphical methods – graphs, number lines) that he drew on the board - only once did I see a chart that he made to illustrate 'fractions and percents equivalence' as stated in the *Investigations*, and an aid to assist students make conversions.

Tim's' students mainly worked independently and had limited sharing and discourse with each other or teacher. He used *Investigations* as a supplement to the *Mathematics In Action*. But once in a while Tim would let students do an activity. The activities enabled Tim to diagnose that some of his students had difficulties with multiplication. He stated that, "My students do not know their times table well. Most of them could not even use the tiles to make a rectangular array. But students who knew their times enjoyed the activity and had a lot of fun. Some do not even know the product of zero and nine."

Discussion

The discussion below integrates the three key questions that this study sought to investigate, the conceptual framework (ZPD) and data results.

Teachers' Pedagogical Beliefs And Meaning Of Investigations Curriculum

All the four teachers had a positive attitude towards *Investigations* even though they practiced it differently. Leroy perceives the *Investigations* approach as better - a move from individualized learning to hands-on activities, higher students' thinking levels and cooperative learning. Leroy seems to belong to both the instrumentalist and the learner-focused views described by Ernest (1989), and Kuhs and Ball (1986). Both Doty and Kim belong to Lerman's (1983) fallibilist view. Doty came to the realization that *Investigations* was good for her students and referred to it as an eye-opener. The platonist model (Ernest, 1989), describes Tim's practice but not his beliefs. Teachers' pedagogical beliefs are not unshakeable truths when perturbed. Even Tim who is performance-and-content focused stated that *Investigations* made students to think critically.

Teachers' beliefs can change, but they need time to unlearn traditional pedagogical beliefs in this reform era. Time to get answers as to why teachers' old pedagogical beliefs fail and that *Investigations* implemented properly work better.

Relationship Between Teachers' Meaning-Making Of Investigations And Their Practice

All the teachers used aspects of *Investigations.* Some of the classes used aspects of it in a traditional manner where the expert who knew it all gave explanation of the concept while listeners meekly accepted. Other classes did much better with *Investigations*, especially classrooms that employed cooperative learning. For learning to take place in a ZPD, it is the collaboration and the heart to share ideas that count and not the expertise. By working as groups, each student was forced to rise above self by building on the contributions of other members. For example in Leroy's class, students learned by interacting with peers and the teacher, and through manipulatives and a contextual setting. Both the teacher and students promoted classroom discourse, by asking probing questions, the 'why' and 'how' types of questions.

Students influence one another, the teacher influences students, and students in turn stimulate the teacher's ways of thinking with their divergent thoughts, as was the case in Class B. Besides the teachers including their students' thoughts, they also collaborated with each other and felt that they needed more dialogue with different people. It is noteworthy that in classes where traditional mathematics teaching prevailed boredom reigns (irrespective of curricula), but there was enthusiasm with *Investigations* activities.

Changes Teachers Undergo When They Implement Investigations

A major change for teachers was to create a classroom where the teacher is not the sole authority in mathematical knowledge. To transcend procedural learning to encompass conceptual understanding, the learning of mathematics should be transformative and not transmissive (John-Steiner & Mahn, 1996). Spark (1997) argues that it is difficult to teach using inquiry methods if one has not learned that way. Teachers themselves need experience in applying mathematics (exploring, guessing, testing, estimating, arguing and proving) in a manner that encourages active engagement with mathematical ideas (Battista, 1994). Such experiences would enable teachers' transition to appropriate pedagogical beliefs. Schifter (1996) postulates that a way of assisting teachers to gain newer conceptions is by being students themselves in classes where the newer teaching approach is enacted.

Teachers pedagogical beliefs can change from being teacher-centered to student-based if they take time to create a collaborative environment where mathematical discourse is encouraged. *Investigations* requires students to come up with their own solutions on their own or in groups then make a presentation of their finding to the entire class. This enables a teacher to assess the different strategies used by different groups, as well assess the difficulties encountered and the weakness of certain strategies. All in all, each student would have his or her thought-processes provoked.

A second area of change was on the use of technology. Teachers questioned the role calculators play in *Investigations* and complained that they had no skills in organizing a computer-based class involving *Investigations* software (e.g., Trips in *Patterns of Change* unit) even though some did use technology.

A concern voiced by all teachers is that *Investigations* lack sufficient practice and does not enhance students' mastery and knowledge of basic mathematics skills. All the teachers lamented that the assessment book did not test on all the key concepts learned in certain units so they created their own tasks. They want a workbook for reinforcement, as was the case with traditional approach.

Other difficulties that teachers found were on (a) how to build mathematical concepts and skills that students have not been introduced to and are experiencing for the first time at a higher grade level, (b) difficulty completing all the nine units or choosing the significant units to handle before the school year runs out, (c) the four teachers were unfamiliar with the structure of the *Investigations* units and the reading of the teacher's manual, and (d) making copies of students' worksheets and overhead transparencies, which was considered by the teachers to be exhausting and time consuming. (Students workbooks are available now that the district has adopted the curriculum.)

Conclusion And Suggestions

Indeed, there exists a relationship between a teacher's pedagogical belief and practice; and beliefs change as the teacher's knowledge base broadens, as stated in prior studies. Key factors found in this study that are needed for a teacher to successfully implement inquiry-based curricula like *Investigations* so that students are engaged in meaningful learning include (a) provision of in-service courses, (b) having a mathematics resource person in the building, (c) broadening the mathematical content knowledge of teachers, and (d) coordinating teachers' collaborations by enhancing more dialogs with teachers as teams or with other colleagues in the district.

To create student-based classrooms where divergent thinking is promoted requires teachers to be flexible and broad-based in mathematical knowledge. Professional support is needed for smooth transition from the traditional to the *Investigations* curriculum. Despite, *Investigations* being well laid out for teachers and the provision of classroom tapes complementing *Investigations,* teachers would still like a more intensified support. This calls for supportive, effective, and continual professional development to become a reflective teacher.

The findings of this study also have implications of how teacher preparation programs and professional development ought to be conducted. In-service training ought to be classroom-based as opposed to workshops, training or seminars outside of classroom without students. Clearly teachers' education should be interactive and contextual, to enable teachers create mathematical learning communities.

The way ahead in the 21st century is to teach mathematics using research-proven instructional approaches. This study focused on only four teachers but the findings provide useful insights to school districts that adopt *Investigations* or any reform-based mathematics K-5 curricula. The study has described the multiple realities that existed and has documented the types of workbooks and structure of units, that teachers would like included in *Investigations* kit as well as, in professional development programs but further research is called for in other contextual and curricula issues not pursued here.

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